



Systems Engineering Streamlines Department of Defense Technology Integration Processes

Matthew Sablan

Systems engineering (SE) has become a central focus for research and development as well as the acquisition of military vehicle systems and equipment. The Department of Defense's (DOD's) SE processes have streamlined acquisitions, life cycle management and logistics management programs. In fact, an outlook on SE will be included in an upcoming Society of Automotive Engineers (SAE) publication. This outlook is provided by two SE process subject-matter experts (SMEs) — Robotic Systems Joint Project Office (RS JPO) SE Team Leader (TL) Mark Mazzara and U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) National Automotive Center (NAC) Engineer TL for Knowledge Mining, Assessment and Forecasting Ramakrishna Iyer. The chapter, *Systems Engineering for Military Ground Vehicle Systems*, discusses SE from DOD's point of view.

"A number of SAE members have an interest in systems engineering," stated Oakland University Professor Dr. Subramaniam Ganesan, chief editor of the upcoming SAE publication, as he explained why he approached the two to write a chapter covering the latest advances in SE. "DOD and NASA are involved with complex and large systems, and less complex products will follow the same practices. Government, DOD and NASA are the leaders in SE."

Understanding SE

In their chapter, Mazzara and Iyer define SE as "disciplined technical planning and management" or "the process by which a stated user desire is transformed into a tangible product that is optimized in terms of affordable operational effectiveness."

The Army — with its vast array of products, vehicles, equipment and systems — benefits from an SE approach. The Army's current acquisition and design processes are complex and multifaceted, requiring multiple complicated and detailed wall charts to guide its many phases:

- Materiel solution analysis.
- Technology development.
- Engineering and manufacturing development.
- Production and deployment.
- Operations and support.

Mazzara and Iyer write that the "wall chart depict[s] how a required operational capability is transformed from a stated user desire to an affordable, operationally effective, tangible, fielded and sustainable product or capability." SE assists requirements management and development by ensuring adequacy and maintaining integrity between the different levels of requirements. Requirements management is critical to a program and properly addressing it is one of the largest benefits that proper SE provides.

SE Yields High Returns

Proper SE identifies risk factors early in a program or product's life cycle, allowing for development of timely solutions to account for and mitigate risks. The sooner problems are identified, the easier and less costly it is to build in solutions or avoid the risks entirely with different, less risk-intensive solutions. "The more that's done upfront, the greater the probability of ultimate success," Mazzara noted. "This keeps risks from blindsiding you."

Disciplined requirements management also helps DOD identify customers' needs by helping systems engineers identify what they need and recognize how those needs will interact with existing systems that may potentially conflict

with other needs or component requirements. Iyer explained this idea using a military bridge as an example of an item for which a Soldier may have many different requirements: durability, weight-carrying limits, location over swift-moving or still water, permanent or temporary status, time needed to deploy, length, weight and portability.

Now consider just two of these factors: length and portability. If the bridge needs to be 20 feet longer, its weight increases proportionally, presenting transportation challenges. In this example — in extremely simplified terms — SE is the process of taking these two requirements and conducting a delicate balancing act between them to develop the technologically feasible solution.

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SE looks at all variables and weighs several possibilities. It then delivers to the customer the best capability that technology currently allows. Work done early in the process to analyze

The Battery B, 2nd Battalion, 12th Field Artillery Regiment Fire Direction Officer, 1LT Matthew Basilio, kneels beside his vehicle while scanning the area below a bridge in the battalion's operational area. Varying vehicle and bridge weight requirements necessitate a detailed SE approach by DOD to best serve warfighters. (U.S. Army photo by PFC Kimberly Hackbarth.)

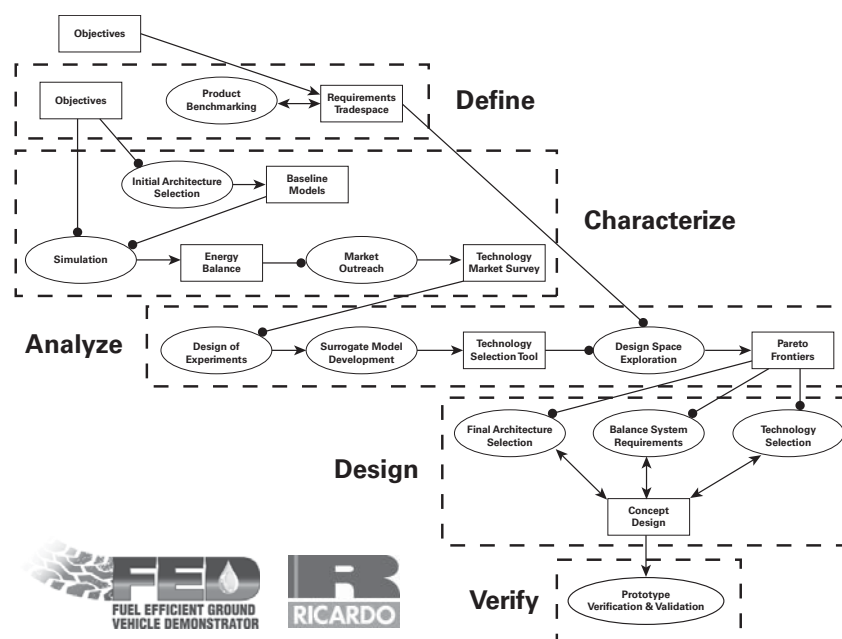


The 1st Marine Logistics Group (1st MLG) received four Mine Resistant Ambush Protected All-Terrain Vehicles (M-ATVs) Nov. 9, 2009, to train more than 200 operators and mechanics on this new piece of equipment in the USMC arsenal. TARDEC associates were directly involved in SE planning for the M-ATV. (USMC photo courtesy of 1st MLG Public Affairs Office.)

needs and compare them with currently existing systems ensures compatibility and proper prioritization. Continuing the bridge example, it may be determined that the most important factor is weight. After all, the most durable, longest, quickest-deploying bridge in the world is not of much use if it weighs 30,000 pounds and is not easily movable. Other requirements, such as weight-carrying limits are also important.

The sooner systems engineers listen to customers, the sooner requirements information can inform solutions building and balancing requirements. With the bridge, it may be determined that in its destination location, certain chemicals or temperatures may exist that make particular materials better choices than others. Only by listening to the customer and doing the proper upfront research can the systems engineer determine the feasibility of solutions. To find the “voice of the customer,” systems engineers go through DOD’s

Joint Capabilities Integration and Development System (JCIDS) process, by which capability needs are developed and documented. JCIDS also sets up the operational requirements for any new systems or system-of-systems to follow to be successful.



This chart depicts the phased elements Ricardo used for TARDEC FED concept development. The design concept approach was systems thinking, which focused on system-wide improvements over component optimization. By segmenting the process into multiple steps, the FED used an SE approach with each phase building up to the next in a systematic, disciplined manner. (Image courtesy of Paul Luskin, Ricardo plc.)

TARDEC has already successfully applied its SE expertise to various programs. These program tests of the program have allowed DOD to refine the process to get the best results possible from the resources available. One program that exemplified TARDEC’s SE approach is the Fuel Efficient ground vehicle Demonstrator (FED) program.

FED Program Achieves Results

The SE approach is a versatile tool that can be applied in many ways. TARDEC FED Team Leader Carl Johnson explained that both the FED program’s branches used SE approaches to reduce risk. The program’s requirements were primarily benchmarked from the High Mobility Multipurpose Wheeled Vehicle (HMMWV) program, creating a set of goal-focused requirements to build toward rather than solutions-focused requirements. By having the goal of a vehicle that met certain benchmarks as opposed to one that used a certain construct,



This concept drawing of the Ricardo-designed FED offers a designer's rendering of how the vehicle may look upon completion. After thousands of models and countless hours of analysis, the program is proceeding to design and build a vehicle capable of dramatically improving fuel economy in the field. (Image courtesy of Ricardo plc.)

many different combinations could be explored. Ultimately, there were only a few pages of requirements. "We were specific but minimal. We didn't want to be rigid," Johnson remarked.

Data-Driven SE Finds Solution

For the FED program, "The Ricardo Group, one of TARDEC's many industry partners, took a data-driven approach," Johnson explained. Working with TARDEC, Ricardo conducted tens of thousands of simulations at the subsystem level. The modeling and simulation (M&S) process allowed TARDEC and Ricardo to identify the "efficient frontier" of design configurations. This complex SE approach helped determine which combinations of technologies had the greatest chance of meeting TARDEC and DOD requirements. "It helped identify the sweet spots," TARDEC Engineer Rob Berlin noted. "Now, we can validate the models on the back end." Multiple iterations narrowed down the field of thousands to three potential architectures.

Together with two embedded TARDEC engineers, Ricardo

documented the SE approach to the FED program. "We wanted a rigorous SE and data-driven approach to select technology and develop architectures," Ricardo Vehicle Engineering Manager Paul Luskin asserted. One area looked at was the vehicle's energy balance, which is the breakdown of how energy leaves the entire vehicle system. By looking at this, the engineers were able to find high-impact areas to focus on. Through their technology market survey of more than 100 different suppliers, the engineers expanded their understanding of various potential components, highlighting the biggest efficiency gains possible with limited resources.

Nontraditional SE Equally Effective

TARDEC, in conjunction with other industry partners, looked at a differing approach unofficially referred to as the "Monster Garage." As TARDEC Engineer Rachel Agusti explained, "It was SME driven. SMEs from academia, industry and government were all in one room." They worked together in groups to rank potential technologies. Initially, they analyzed the technology

that was submitted and publicly available. "They drilled down together into concept vehicles," Johnson noted. TARDEC put these six concept vehicles through their paces with M&S tools and used valid drive cycles from theater and developed thorough duty cycle experiments to define each concept's potential duty cycle performance.

By combining industry and academic experts, TARDEC was able to draw on a variety of experience, fostering unique viewpoints and suggestions and allowing each group to view the problem holistically. After the M&S, TARDEC engineers were able to take the concepts that the working groups put forward and select the solution most likely to yield the desired results, saving the expense of having to physically build each demonstrator and test it live.

With Ground Systems Enterprise organizations such as TARDEC and Program Executive Office (PEO) Ground Combat Systems, PEO Integration, PEO Combat Support and Combat Service Support, and U.S. Marine Corps (USMC) PEO Land Systems collaborating with partners from industry and academia, the government will continue to benefit from the process SE affords and demonstrate its role as a leader to innovate and use partnerships to secure new ideas and technologies.

Editor's Note: RS JPO Engineer Mark Mazzara, NAC Engineer Ramakrishna Iyer and FED Engineer Carl Johnson contributed to this article.

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